THESIS FOR THE DEGREE OF LICENTIATE OF ENGINEERING

# Sustainable service-based business models

## Exploring the potential of digital technologies in industrial companies

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# ABSTRACT

Industrial companies are continuously looking for solutions to increase their competitive advantage and become sustainable. Many industrial companies have prioritised economic sustainability as means of success. However, recent decades have revealed many external pressures and these have highlighted the need for more sustainable organisations. The growing interest in sustainable alternatives has shed light on various business models which promote balance and support the path towards a more circular economy.

This thesis aims to promote sustainable, service-based business models by identifying the challenges and opportunities encountered in this transition. Further, it explores the methods, tools and frameworks available in the literature and identifies the sustainability-related elements and KPIs.

The results showcase a list of challenges faced by industrial companies in developing service-based business models. For instance, there is a lack of consensus on terminology for business models, sustainability and digital technologies. Although the studies included in this thesis are from different industry sectors, the challenges found were similar.

The increasing availability of digital technologies and engagement of global organisations may support the development of service-based business models. In addition, new technological opportunities, regulations and incentives can promote collaboration and responsibility in companies.

This thesis systematises the existing methods, tools and frameworks and shows the extent to which they support companies as they move towards sustainability. It also provides recommendations and relevant considerations for the future development of new methods and tools.

This research contributes to the systematisation of knowledge gained from the different terminologies used to refer to service-based business models. It also captures unprecedented experiences from multiple industries, such as recyclers and service providers in the maritime sector. This thesis' findings can inform and support companies on their path to understanding and implementing service-based business models.

**Keywords**: service-based business models, sustainability, digitalisation, servitisation, digital technologies.

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# APPENDED PAPERS

| | |
|---|---|
| **PAPER 1** | González Chávez, C. A., Despeisse, M., & Johansson, B. (2021) *State-of-the-art on Product-Service Systems and Digital Technologies.* In: EcoDesign and Sustainability I: Products, Services, and Business Models. Yokohama: Springer Singapore. pp. 71-88. |
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| **CONTRIBUTION** | Principal author. Clarissa planned and conducted the literature review with Maria. The co-authors provided input on the structure of the article. Also, they reviewed the material and provided supporting comments. |

# TABLE OF CONTENTS


1 INTRODUCTION ..... 1
1.1. Background ..... 2
1.2. Vision and aim ..... 3
1.3. Research questions ..... 4
1.4. Delimitations ..... 4
1.5. Thesis structure ..... 5
2 FRAME OF REFERENCE ..... 7
2.1. Sustainable business models ..... 8
2.2. Service-based business models ..... 8
2.2.1. Product-service systems ..... 9
2.3. Defining value ..... 9
2.4. Sustainability implications ..... 10
2.5. The effect of digitaliSation ..... 11
3 RESEARCH APPROACH ..... 13
3.1. Philosophical and theoretical perspective ..... 14
3.2. research design ..... 15
3.3. Research methods ..... 17
3.3.1. Study A (Paper 1) ..... 17
3.3.2. Study B (Paper 2 & 3) ..... 18
3.3.3. Study C (Paper 4) ..... 18
3.3.4. Study D (Paper 5) ..... 18
4 RESULTS ..... 19
4.1. Challenges and opportunities of industrial companies to develop service-based business models ..... 20
4.1.1. Challenges of industrial companies iN developING service-based business models ..... 20
4.1.2. Opportunities of industrial companies to develop service-based business models ..... 22
4.2. Inclusion of sustainability in methods and tools for the development of service-based business models ..... 25
4.3. Developing Service-Based Business Models In Industrial Companies ..... 28
5 DISCUSSION ..... 35
5.1. This thesis in relation to previous work ..... 36
5.2. Answering the research questions ..... 37
5.3. Methodological discussion ..... 39
5.4. Contributions of this thesis ..... 40
5.5. Future research ..... 41
6 CONCLUSION ..... 43

PAPER 1
PAPER 2
PAPER 3
PAPER 4
PAPER 5

# 1

# INTRODUCTION

*This chapter presents the background to the thesis, its research vision, purpose, and aims. The research questions guiding this work are also provided, alongside the thesis structure and delimitations.*

This thesis focuses on the development of service-based business models; it evaluates the challenges and opportunities of implementing service-based business models, including sustainability and digitalisation. Further, it examines the available methods and tools in the literature for understanding how companies can develop sustainable service-based business models. This first chapter introduces the thesis, includes the background to the presented research and states the research problem.

## 1.1. BACKGROUND

Companies are continuously trying to create and capture value, to achieve a competitive advantage. Recent decades have demonstrated that product-centred business models do not guarantee success (Kindström, 2010). Companies are shifting towards service-based business models to increase their offerings portfolio, generate additional revenue and profits, retain customers and engage with new ones in tighter relationships (Gebauer, Fleisch, & Friedli, 2005). The growing interest in service-based business models has led companies to explore value-adding activities, such as service provision added to tangible products, the sale of services to cover specific needs and results-based offerings (Tukker, 2004).

After the tumultuous years of global conflict in WWII, countries were exposed to fast-paced industrial development which revolutionised the way people worked, socialised and lived. The post-war world made room for geniuses such as Henry Ford. His proposal for mass production contributed to societal development by adopting a product-centred approach, promoting consumption and ownership while keeping pricing standards reasonable (Vandermerwe, 1993). Unfortunately, the practices and consumption habits that sprouted during this time led to an unsustainable economy based on a linear approach known as "take-make-dispose" (MacArthur, 2013). In this economic system, value was generated by producing and selling as many products as possible, an unsustainable approach.

Fast-forwarding in time, sociologist and economists debated the post-industrial society. They forecast drastic changes in the way value was perceived, as the economic system that had become standard could not last long. By the early 1970s, Daniel Bell was already predicting a service-dominated economy, in which companies wanting to remain competitive would have to find new ways of capturing value through intangible offerings (Bell, 1976). This prediction was accurate and, soon after, some analysis began to show that economic growth no longer relied solely on manufacturing companies and their tangible goods (Witt & Gross, 2020). Instead, the service sector's strength was becoming increasingly visible, revolutionising companies' organisation and the way they developed their offerings.

To disrupt the linear economy, Vandermerwe and Rada (1988) proposed servitisation. This work has become widely accepted in management and engineering literature as one of the starting points for discussing service-based business models, at a time when industry was flooded with reflections and changes. It has been said that servitisation strengthens customer relations, creates new and more robust revenue streams and ensures competitive advantage and market presence by establishing higher barriers to competitors (Baines et al., 2011; Baines et al., 2009).

It is worth mentioning that *servitisation* refers to the process. A company that *servitises*

transitions from its previously product-centred approach towards a *service-based business model*. In this thesis, the use of the term *service-based business models* is no different to the essence of servitisation and describes it mainly as a unit rather than a process.

Previous decades have shown a long and varied adaptive process in which companies have tried to gain a deep understanding of their customers. Companies have begun to step away from the one-size-fits-all approach and find customised offerings that, through a mix of tangible and intangible assets, earn them an advantageous market position (Sousa & da Silveira, 2019). Additionally, political, economic and social restructuring have influenced how organisations perceive, create and capture value. Governments, in collaboration with industry, have continuously created foundations, agendas and guidelines which could impact society positively. An example is the Ellen MacArthur Foundation, a UK registered charity launched in 2010 to accelerate the transition towards a *circular economy* (CE) and supported by decision-makers from business, government and academia (MacArthur, 2013). The initiatives sparked by the CE have brought increased attention to service-based business models, as they strongly propose the "performance economy" as one of the main strategies for achieving CE (Stahel, 2010).

Undoubtedly, industry has experienced dramatic changes when it comes to available tools and technologies. Furthermore, the digitalisation trend (and availability of interconnected systems through the growth of connectivity and platforms) has revolutionised and enabled the potential of service-based business models (Kohtamäki et al., 2020). However, it is essential to acknowledge that these simultaneous revolutions bring challenges from the technological, sustainability and human perspectives (Rothenberg, 2007).

Service-based business models are considered by many as tools for promoting sustainability (Evans et al., 2017; Tukker, 2015). For instance, product-service systems (one of the main concepts relating to service-based business models) have been foreseen as an innovation strategy for promoting industrialisation with reduced environmental impact (Manzini et al., 2001). However, some studies claim that failing to establish clear objectives, or have adequate follow-up to business model changes, may have a counterproductive effect from a sustainability perspective (Barquet et al., 2016; Verboven & Vanherck, 2016).

This research sheds light on the main challenges and opportunities of combining service-based business models with digital technologies to achieve sustainable value capture. This study also explores the available servitisation and tools methods to understand the extent to which they include sustainability. Lastly, this research attempts to explore how companies can develop sustainable service-based business models. While previous research has examined the implementation of service-based business models, this study attempts to focus on companies at the middle and end of the product offering lifecycle, with an emphasis on services in the maritime sector and refrigerator recycling.

## 1.2. VISION AND AIM

Companies today have the potential to grow by complying with customer demands and providing offerings that cover customer needs while contributing to sustainable development and still being profitable. The vision behind this research is to have empowered companies that

create, capture and deliver sustainability values through service-based business models and digital technologies.

Different schools of thought and research communities have attempted to understand the role of service-based business models, sustainability and digital technologies. However, there is still a visible gap in the lack of consensus on terminology. There is also limited involvement from industry. This thesis aims to explore the challenges and opportunities of service-based business models in the context of digitalisation and sustainability. It also aims to identify how methods and tools for sustainable service-based business models include sustainability.

## 1.3. RESEARCH QUESTIONS

This thesis proposes the following three research questions:

***RQ 1) What are industrial companies' challenges and opportunities when developing service-based business models?***

Developing sustainable service-based business models requires an understanding of companies' status quo. The objective of RQ1 is to identify and categorise the main challenges and opportunities of developing sustainable service-based business models, both in literature and in industrial companies. When applicable, the results are combined with challenges that spark from the digitalisation revolution.

***RQ 2) How do methods and tools for service-based business models include sustainability?***

Industrial companies wishing to implement service-based business models may rely on methods and tools to promote a systematic organisation of their ideas and processes. The objective of RQ2 is to define whether the methods given in the literature provide proper support to companies.

***RQ 3) How can industrial companies be supported in the development of sustainable service-based business models?***

The objective of RQ3 is to provide insights into how companies can develop such sustainable service-based business models, focusing on the support provided through the increased availability of digital technologies.

## 1.4. DELIMITATIONS

This thesis is delimited as follows:

- The scope of this research is to explore the potential of service-based business models in industrial environments. Therefore, it does not analyse the implications for governmental or educational organisations.
- The scope of this research does not include the proposal of a framework, method or typology. The focus is on understanding and describing the state-of-the-art.
- This research does not follow an industrial company's transition towards service-based business models. Rather, it takes an exploratory approach, suggesting the

possibility of doing so to different industrial companies.

- This thesis considers sustainability from the triple bottom line perspective, in which environmental, social and economic aspects are explored and suggested as part of the results.

## 1.5. THESIS STRUCTURE

The structure of this thesis includes six chapters. Table 1 gives an overview.

Table 1. Overview of thesis structure

| | |
|---|---|
| **1. INTRODUCTION** | This chapter defines the background, vision, aims, research questions and delimitations. |
| **2.FRAME OF REFERENCE** | This chapter summarizes the theoretical framework and includes sections on servitisation, service-based business models, sustainable value, digitalisation and contextual factors relevant to the industries including in this study (e-waste recycling and maritime shipping). |
| **3.RESEARCH APPROACH** | This chapter describes the philosophical and theoretical perspective, plus the research approach of this thesis. It also presents the research design and methods of the included studies. |
| **4. RESULTS** | This chapter presents the four studies (A, B, C and D) and how they relate to the research questions. |
| **5. DISCUSSION** | This chapter discusses the results of the studies and provides answers to the research questions. It also explains the contributions of these studies and suggests future research steps. |
| **6. CONCLUSIONS** | This chapter summarizes the results of the thesis and establishes concluding remarks. |

# 2

# FRAME OF REFERENCE

*This chapter presents the relevant frame of reference for this thesis. It then provides the research background, introduces the concept of service-based business models, describes sustainability implications and digitalisation. Finally, it describes the additional contextual factors considered in this thesis.*

## 2.1. SUSTAINABLE BUSINESS MODELS

The increasing concern surrounding ecology in recent decades is visible in many industrial contexts. From a strategy and management perspective, it unquestionably creates a new competitive framework for companies (Werbach, 2011). Interest in sustainability in the context of production and manufacturing has also increased dramatically (Herrmann et al., 2014). Global concerns relate to the increased attention given to various forms of damage to our natural environment, as well as global warming and carbon footprint awareness. This is partly a consequence of increased awareness that our environment is at stake.

Business-as-usual is unsustainable. It is imperative to protect life and the environment now and for future generations (Gunasekaran & Spalanzani, 2012). Recent decades have seen many researchers and practitioners examining how their companies can operate whilst striving for success but also contributing to the global need for sustainability. A key term, first mentioned in an academic article from 1957 (Bellman et al., 1957) has been *business models*. This term has created significant controversy in some disciplines. The proposed definitions vary significantly in their constituents. Some have defined business models as structured management tools, considered especially relevant to success (Magretta, 2002). However, as businesses are fundamentally concerned with creating value and capturing returns from it, more information is needed. In simple terms, a model may be defined as "a representation of reality" (Shafer et al., 2005).

In this sense, industry is currently facing a manufacturing model which, to some extent, is still based on the paradigm of unlimited resources and unlimited regenerative capacity. This needs to be updated urgently (Garetti & Taisch, 2012). Some of the opportunities presented by sustainable production and service business operations are yet to be understood by industry. Sustainability can bring new means of differentiation, growth-oriented benefits and new business opportunities for manufacturing companies (Valkokari et al., 2014).

Additionally, the conceptualisation and prioritisation of *value* is highly dynamic. As a result, companies face the undeniably complex challenge of understanding what type of value their customers expect. This is highly necessary for the development of sustainable business models (Sakao et al. 2013). Failing to understand, capture and deliver value means failing to succeed. Yang and Evans (2019) describe the sustainable value proposition behind the identified archetypes of product-service systems which follow a service-based approach.

## 2.2. SERVICE-BASED BUSINESS MODELS

Companies are increasingly considering expanding their offerings into services as a new way of generating additional revenue and profit. This increased interest has emerged, among many other reasons, due to the high level of competition in many markets, the constant pressure for companies to be responsive and have faster communications and decreased profit margins from products. When the interest in services increases significantly, it leads companies to transition from a product-centred business model to a service-centred one (Gebauer et al., 2005).

In recent decades, researchers have proposed different consumption schemes under the belief that they might retain competitiveness while reducing environmental impact. In this way,

concepts such as sustainable business models (Stubbs & Cocklin, 2008), environmental assessments (Morgan, 2012), dematerialisation (Bartelmus, 2003), product-service systems (Mont, 2000) and servitisation (Vandermerwe & Rada, 1988) have increasingly started appearing in literature and among practitioners. The concept of servitisation comprises the proposal that finding value in service-centred offerings instead of product-centred ones might bring many advantages. For instance, it might create firmer and closer relationships with customers, have more precise value propositions and become solution-oriented.

When Vandermerwe and Rada (1988) first introduced servitisation, they also acknowledged that it poses particular challenges for top management. Since then, despite different definitions and approaches, manufacturers' challenges in service-based business models have become a central theme of the literature discussion.

Some authors have examined the many classification schemes developed to distinguish between different types of product-related services (Lay et al., 2009) and how manufacturing industry players become service providers. This shift requires companies to change their strategies and build new business concepts (Neu & Brown, 2005).

### 2.2.1. PRODUCT-SERVICE SYSTEMS

One of the most general concepts within service-based business models is product-service systems (PSS). In their definition, (Annarelli et al., 2016) suggest PSS as a market proposition focusing on the end-user's needs rather than the production process. This allows a need-fulfilment system with radically lower impact but enhanced environmental and social benefits.

Recent decades have shown that the rapid increase in connectivity has led to businesses' digital transformation, ultimately making room for *as-a-service* business models, in which platforms with business networks and ecosystems are increasingly promoted (Banerjee et al., 2011). This has intensified the development of PSS and its interaction with digital technologies (Rachinger et al., 2019).

PSS is not, by definition, a circular business model, but some studies have suggested that it might help organisations reach sustainability targets (Antikainen et al., 2018). Sustainability concerns have created a pull towards digitalised solutions which maximise the use of tangible resources through services. Some of the original definitions of PSS support this point by including dematerialisation and reinforcing sustainability and competitiveness goals (Annarelli et al., 2017).

## 2.3. DEFINING VALUE

The concept of value has changed significantly over time. The first definition appearing in the Cambridge Dictionary refers to "the amount of money that can be received for something" (Cambridge University Press, n.d.). In the 1980s, Porter defined value as a "vertical chain extending from suppliers of resources to firms, through firms, to buyers of products and services from firms". Here it is assumed that value is created by a chain of players (Brandenburger and Stuart Jr, 1996). Zajac and Olsen (1993) define such value as the difference between the benefits and costs created by the collaboration.

When management literature refers to the fact that companies "must capture value", it may

appear somewhat ambiguous. Brandenburger and Stuart Jr (1996) define capturing value using two elements: 1) the willingness of the customer to pay and 2) opportunity cost. Unsurprisingly, although the latter definition relates to usefulness, importance and beliefs, most companies still capture value using a monetary perspective. However, many other aspects explain and justify the role of a company in our society.

Therefore, in this thesis, the use of *value* is contextualised as *sustainable value*, with the three pillars of sustainability (environmental, social and economic) expected to be considered when defining value and, further, when designing a company's offering to its clients and stakeholders (Figge & Hahn, 2004).

The creation of value for shareholders in a firm requires performance to be understood in multiple dimensions. Similarly, global challenges associated with sustainable development may be complex and have various levels, including concerns regarding the triple bottom line. The implications of these challenges showcase every aspect of a firm's strategy and business model (Hart & Milstein, 2003).

In the context of service-based business models, the idea of capturing sustainable value centres on decoupling the value offering from the ownership of an asset into providing value in use. It thus decouples economic success from material consumption and potentially reduces the environmental impact of economic activities, such as sales (Baines et al., 2007).

## 2.4. SUSTAINABILITY IMPLICATIONS

Given the constraints on resources and degraded ecosystems, awareness of sustainability in business has increased in recent decades. Sustainability is said to be "the only business success strategy of the future", with sustainable business development applying sustainability principles to business operations (Danciu, 2013).

In 1987 the Commission on Environment and Development (WCED) proposed a definition of sustainability which became widely adopted. It defined sustainable development as: "meeting the needs of the present without compromising the ability of future generations to meet their needs" (WCED, 1987). This definition requires a framework to be considered that integrates three dimensions of performance: social, environmental and financial. Slaper and Hall (2011) also refer to this as "the Three Ps": people, planet and profits. Thus, a sustainable company helps capture and deliver value whilst mindful of the triple bottom line.

The challenge of global sustainability is highly complex, multidimensional and rapidly rising. Firms face increasing challenges to reduce waste in their current operations whilst redesigning their available competencies towards more sustainable technologies and more robust skillsets. Simultaneously, they face the challenge of interacting and having extensive dialogues with external stakeholders to develop sound, triple bottom line solutions. Addressing the many existing sustainability challenges may promote value creation and might represent one of the most underestimated future avenues of profitable growth (Hart & Milstein, 2003).

Companies' interest in sustainability is still driven by their desire to reduce costs and material and energy inputs. However, stricter legislation and increasing public interest may steer the future of companies and their markets towards more sustainable, cleaner and socially sound

practices (Despeisse et al., 2011).

Boons and Lüdeke-Freund (2013) examine the elements needed to market a sustainable innovation. These are: value proposition, supply chain, customer interface and financial model. Further, they discuss how service-based business models may support these elements. There are undeniable challenges in these processes but their evident advantages accentuate the need to explore further service-based business models.

These initiatives should be taken with a pinch of salt, as some authors have examined the paradox of sustainability in service-based business models. PSS is not a sustainability panacea (Tukker, 2015); service-based activities may have environmental benefits. However, in principle, the use of fewer product-based offerings replicates the ecological advantages of PSS.

## 2.5. THE EFFECT OF DIGITALISATION

*Digitalisation* refers to the digital representation of a product or service that allows easier delivery and manipulation of the aforementioned assets (Bitner et al., 2010). *Digital technology* has emerged as an umbrella term which includes the tools used to achieve digitalisation. For instance, the Internet of Things (IoT) was a term first coined by Ashton (2009) to describe the interconnection of physical objects through added sensors. IoT has impacted companies and became a vital element of the Fourth Industrial Revolution (Suppatvech et al., 2019).

The way that digitalisation impacts entire business models cannot be ignored. Some researchers have used the term *digital business models* to refer to business management activities in a company's operations which incorporate digital technologies. Some of the most common are mobile devices, analytical analysis tools, sharing platforms and IoT (Luz Martín-Peña et al., 2018).

Evangelista et al. (2014) explain that the move towards a digital society is not about getting people to use technology but about its actual impact and how it transforms people's lives. Dealing with digitalisation and assessing its socioeconomic impact requires comprehensive indicators which showcase the larger-scale economic and social impact. A major challenge lies in organisational capabilities, such as configuring hardware components to sense and capture information (Lenka et al., 2017).

Academia and industry both currently attribute major opportunities to the emergence of *big data*, a term relating to the large volume of information and its variability, variety, velocity, veracity and value (Chen & Zhang, 2014). The potential big data provides for developing new service-based business models is yet to be explored. However, digitalisation and servitisation must converge, as the combination of new technologies, connectivity and data analysis goes hand-in-hand to create new value propositions. Doing this requires firms to cover the gap between the rapid speed of digital transformation and the pace of their adaptation process (Luz Martín-Peña et al., 2018).

Digitalisation enables servitisation through the data made available during the lifecycle of an offering. Some researchers have examined companies' opportunities to become more efficient, flexible and practical by ensuring precise customer needs are covered when analysing product lifecycle management (PLM) data (Xin & Ojanen, 2017). Others discuss such aspects as the

importance of information as a source of value generated through data flows and analysis (Cenamor et al., 2017). As Rust claims, “the service revolution and the information revolution are two sides of the same coin” (Rust, 2004). Nevertheless, compared to more traditional products and services, there has only been limited exploration of the understanding of how to commercialise data and information and enable servitisation.

# 3

# RESEARCH APPROACH

*This chapter presents the rationale behind the research approach to this work. It also describes the author's philosophical worldview and how it has influenced the research approach, design and methods. It also provides details of the design and methods used in this research in terms of the research questions and studies.*

## 3.1. PHILOSOPHICAL AND THEORETICAL PERSPECTIVE

Humans are curious by nature and feelings of dissatisfaction, limited understanding, or inadequate answers, leads them to do research. Researchers cannot deny their life paths. Their mixture of upbringing, past experiences and ideas sets the stage for them to act in a certain way as they search for answers through their academic journey.

Before starting this PhD journey, the author studied industrial engineering and advanced manufacturing systems and became increasingly curious about the managerial aspects of production. Master's studies then brought increasing interest in understanding the new economic paradigms which continue to shape the world.

This research identifies pragmatism as a worldview developing from actions, situations and consequences rather than antecedent conditions (Creswell, 2003). The philosophy behind pragmatism focuses on understanding what works and which solutions relate to the problems posed (Patton, 1990). This research paradigm accepts as true the methods and solutions that work at the time. It typically poses research questions that begin with *what* and *how*.

Pragmatism opens the door to multiple methods, worldviews and assumptions, plus different forms of data collection and analysis. Furthermore, this worldview allows the inclusion of tools from both positivist and interpretivist paradigms. In other words, the researcher does not centre the selection of methods on the core of the research objective. Rather, the idea is to understand the research problem and use all available approaches to understand the problem (Creswell 2003).

Understanding philosophical foundations facilitates research design. To this extent, there are two contracting paradigms on how to conduct social science research: positivism and social constructionism (Easterby-Smith et al., 2012). It is essential to understand that polarities in research represent a spectrum. The outcomes of this thesis has not followed a pure approach. Rather, it includes a mixture of elements from different approaches. This researcher believes that business models may seldom be studied objectively. The definition of value at their core may be a subjective and firmly context-dependent concept.

The author's epistemological perspective connects well with the propositions of social constructivism (Dalton, 1959;Watson, 1991). This philosophy defines reality as determined by people rather than by objective and external factors. It positions the researcher to appreciate constructions, meanings and experience. The research methods proposed by this philosophy align with the exploratory nature of this work (Easterby-Smith et al., 2012), which prioritises qualitative data, with research growing out of researchers' confusion and irritation. Rather than formulate explicit hypotheses and guides for this work, the author frames open questions about the current situation and perplexing elements.

The guiding pragmatism and social constructionism of this research support its industrial nature. Developing research that is applicable in supporting companies requires practical solutions to real-world problems. Thus, the cases covered in this thesis' applied research support the development of theory by accepting research problems posed by stakeholders and research communities and by proposing actionable, evidence-based recommendations (Guest

et al., 2013).

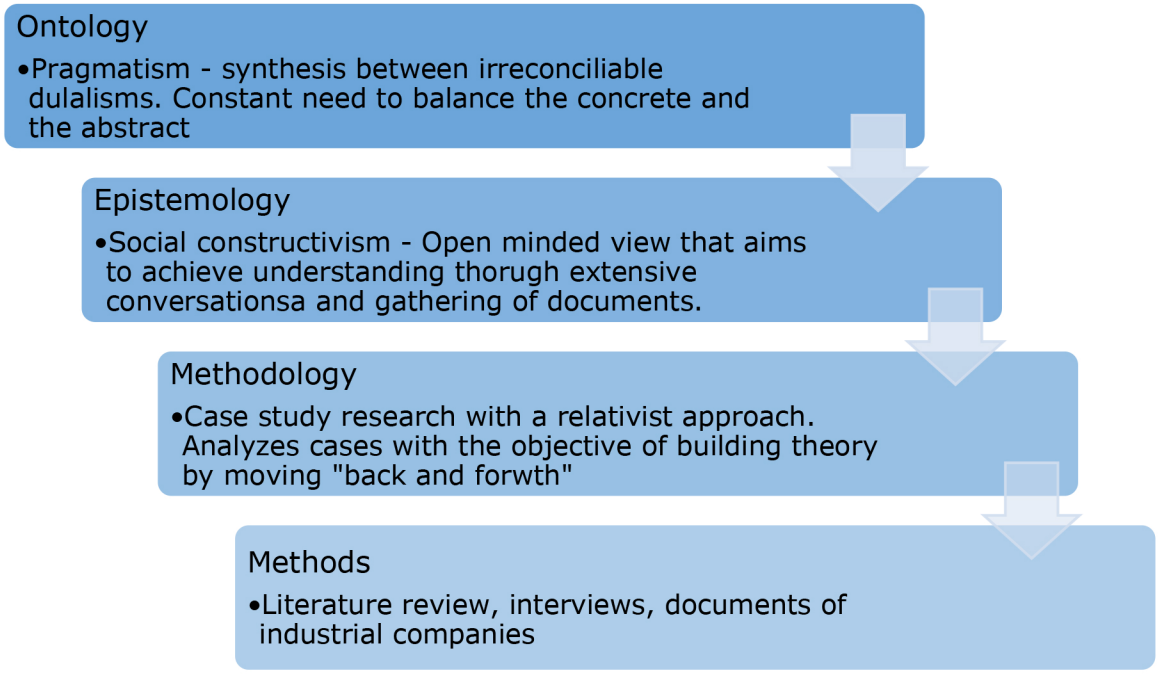


Figure 1. Research framework of this thesis (Easterby-Smith, Thorupe and Jackson 2005, Crotty 1998)

## 3.2. RESEARCH DESIGN

This thesis work bases its methodology on Creswell's proposal (2003) in which achieving a research approach entails a philosophical worldview, a research design aligned with the researcher's worldview and research methods that systematically reach the research objectives.

This researcher has not centred her chosen method on the core research objective. Rather, the idea is to understand the research problem and use all available approaches to understand the problem (Creswell 2003). The studies followed a literature review, single case study and multiple-case study, all with theoretical and empirical priorities, as shown in Figure 2. Case studies are predominantly qualitative and favour methods such as interviews and qualitative data collection (Yin, 2018). The case-study approach fits best with the relativist approach proposed by Eisenhardt (1989), which draws inspiration from both positivist and constructionist positions. This selection is justified by a desire to be flexible about the design of the case studies, plus an interest in using different data collection methods.

Figure 2 shows the development of the four studies, with the colour gradient describing the extent to which the author involved theoretical and empirical studies. The theoretical approach was based on literature studies; this helped define the field and identify the research gap. The empirical studies included observation and data collection from companies, plus secondary sources supporting the inductive research process.

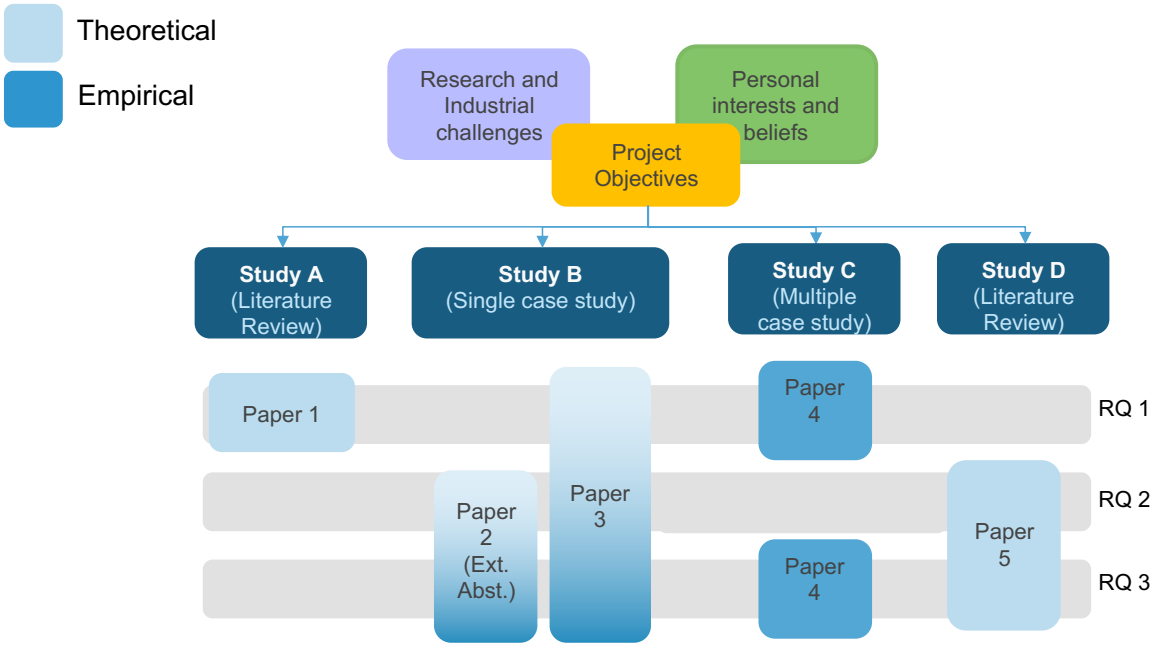


Figure 2. Research questions, appended papers and studies

***RQ 1) What are industrial companies' challenges and opportunities when developing service-based business models?***

Studies A, B and C provide answers to RQ1. Study A took a theoretical approach based on a literature review (Tranfield et al., 2003) which aimed to understand the field and the interactions between digital technologies and PSS. Study B, a case study, begins with a literature review, collects data from a recycling company (and secondary data from other recycling companies) and conducts a feasibility study of the use of digital technologies in developing service-based business models. Study C, a multiple-case study, explores service providers in the shipping industry and uses semi-structured interviews, company visits and secondary data to document their insights into service-based business models, sustainability and digitalisation.

***RQ 2) How do methods and tools for service-based business models include sustainability?***

Studies B and D provide answers to RQ2. As a preliminary study, Study B addresses the potential for using a specific tool to address an industrial problem requiring immediate action. Study D takes an evidence-based approach to a systematic literature review, identifying the methods and tools for servitisation transitions and analysing whether or not they integrate sustainability principles.

***RQ 3) How can industrial companies be supported in their development towards sustainable service-based business models?***

Studies B, C and D provide answers to RQ3. The literature review in Study B was part of the methodology aimed at identifying the main value elements of refrigerators at end-of-life. This was a first step towards understanding potential new business models and the results were documented in constant communication with the case company. Study C used an empirically

focused multiple-case study to highlight the support requirements of service providers in the maritime industry. Study D used a systematic literature review to disseminate the different considerations of existing methods and tools for sustainable servitisation and identified gaps for future research.

## 3.3. RESEARCH METHODS

This subsection briefly describes the method followed in each study, as shown in Table 2. The design of the studies was adapted to contribute to each study's purpose and gather and analyse data.

Table 2. Research Design

| Study | **Paper** | **RQ1** | **RQ2** | **RQ3** | **Research design** | **Data collection and analysis** |
|---|---|---|---|---|---|---|
| **Study A** | Paper I | x | | | Literature review | Systematic literature review with deductive coding. |
| **Study B (STENA)** | Paper 2 (Extended abstract) | | x | x | Case Study | Five visits to STENA's recycling plant in Halmstad, Sweden and 1 to STENA's recycling plant in Cavenago di Brianza, Italy. Literature review which captured State of the Art and value at EOL of refrigerators. Feasibility study performed through workshops and research project's outcomes. |
| | Paper 3 | | x | x | | |
| **Study C (ECOPRO-DIGI)** | Paper 4 | x | | x | Multiple-case study | Initial meetings and keynotes from experts and managers in the maritime industry. Literature review on sustainable business models in shipping. Gathering company information, company visits, and semi-structured interviews conducted and coded by multiple researchers. |
| **Study D** | Paper 5 | | x | x | Literature review | A systematic literature review was conducted and coded inductively. |

### 3.3.1. STUDY A (PAPER 1)

Study A aimed to understand digital technologies and PSS interactions and document their enablers and challenges. The study involved a systematic literature review with a theoretical approach (Tranfield et al., 2003). This study followed a deductive coding process for the

selected articles' content (Saldaña, 2013). The author decided to follow this methodology because it promotes unbiased outcomes and reliable knowledge development in context-sensitive research topics.

### 3.3.2. STUDY B (PAPER 2 & 3)

Study B follows a case-study research method. It investigates a contemporary phenomenon in-depth, within its real-world context (Yin, 2008) whilst focusing on a refrigerator recycling company. This study aimed to explore the potential for capturing sustainable value through service-based business models in a refrigerator recycling plant. The study was conducted in three stages: planning, reviewing and exploring (Tranfield et al., 2015).

Paper 2, in which the planning took place, describes the problem: "to explore the challenge of e-waste in the refrigerator recycling industry and propose that alternative solutions might be found by exploring uncaptured value and creating new business models". It also establishes two research steps: (1) a literature review aimed at understanding the value elements at end-of-life of refrigerators and (2) a single-case study.

Paper 3's aim was reviewing. It comprises an exploratory literature review which also used secondary data. Using a literature review, the objective was to identify the remaining value at EOL refrigerators and possibilities for further treatment.

An exploratory stage was also conducted; this is still part of the ongoing research process. In this stage, two value-capture alternatives were proposed to the company. The first one included creating a business model from the data from incoming refrigerators. The second suggested automating the removal of the compressors (in the back of the refrigerators). This is a key element of value retention. These ideas were tested through company visits, a data-gathering process (collecting images), use of visual recognition software to test feasibility and workshops with the company to further explore the proposed ideas' potential.

### 3.3.3. STUDY C (PAPER 4)

Study C explores the perception of the maritime industry regarding service-based business models, sustainability and digitalisation. The methodology follows a multiple-case study (Yin, 2008) focusing on eight companies. The study includes a literature review which helps position the research topic in the context of maritime shipping. The collected data includes information from meetings, company visits and semi-structured interviews with experts and managers. The interviews were recorded, transcribed and coded inductively by two researchers.

### 3.3.4. STUDY D (PAPER 5)

This study aims to synthesise terminologies around servitisation, using an evidence-based approach to identify how tools, methods and frameworks locate sustainability at the centre of servitisation. The method includes a systematic literature review (Tranfield et al., 2015) which uses a conceptual framework to analyse different elements of the collected literature.

# 4

# RESULTS

*This chapter presents the results of this research in three sections. The first covers the findings on the current challenges faced by manufacturing companies when managing production disturbances. The second presents the results of how technology might support disturbance management. The third highlights suitable managerial practices.*

| SECTION / SUBSECTION | RESEARCH QUESTION | RELATED STUDY | RELATED PAPER |
|---|---|---|---|
| **4.1 RQ1 - Challenges and opportunities of industrial companies in implementing sustainable service-based business models** | RQ1 | Studies A, B, C | Papers 1, 3 & 4 |
| **4.2 RQ2 - Methods and tools that promote sustainability for service-based business models** | RQ2 | Study B & D | Paper 2, 3 & 5 |
| **4.3 RQ3 - Development of a sustainable service-based business model in companies** | RQ3 | Studies B, C & D | Papers 2, 3, 4 & 5 |

## 4.1. CHALLENGES AND OPPORTUNITIES OF INDUSTRIAL COMPANIES TO DEVELOP SERVICE-BASED BUSINESS MODELS

This study presents the results of Study A, B and C (Paper 1, 4 and 5) and their contributions to answering RQ1.

### 4.1.1. CHALLENGES OF INDUSTRIAL COMPANIES IN DEVELOPING SERVICE-BASED BUSINESS MODELS

Study A (Paper 1) examines the challenges of PSS and digital technologies. Early in this study, the authors encountered a major challenge in selecting the right keywords to conduct the literature review.

This challenge is supported by Annarelli et al. (2016). They state that the ongoing research on PSS suffers from a lack of consistency and systematisation of terminology. For example, there is industrial PSS, smart PSS, circular PSS and digital PSS, product-service combinations. Then there is product-to service, servicification, post-mass production paradigm, functional product, total care product, integrated solutions, hybrid product, hybrid value bundles and hybrid value creation. However, all these relate to business models in which services rather than the product are now the basis of value. This justifies the selection of the term *service-based business models* in this thesis.

There is also a lack of systematisation of terminology relating to digital technologies. For example, some of the concepts located in Antikainen et al. (2018) include "CPS", "big data", "data mining", "data analytics", "Internet of Things (IoT)", "mobile internet" and "cloud computing".

Paper 1 lists the challenges of using digital technologies and product-service systems in six main categories: (1) customer perception, (2) technical capabilities, (3) policies and regulations, (4) value of data, (5) data security and privacy and (6) economic feasibility. However, Studies B and C found some additional challenges: (7) lack of support and (8) lack of organisational capabilities. Table 3 includes a description of each challenge.

Table 3. Challenges of industrial companies to implement service-based business models

| | | |
|---|---|---|
| **1** | Customer perception | Some customers were found to have "service-for-free attitudes", become reluctant to pay additional fees for services added to their tangible goods (Coreynen et al., 2017; Ulaga & Loveland, 2014). Also, some organisations fail to understand the benefits of non-conventional business offerings (Nikitakos & Lambrou, 2007). |
| **2** | Technical capabilities | Companies are facing significant requirements to increase their capacity to manage products and service variants (Alghisi & Saccani, 2015). This requirement translates into both digital infrastructure and the availability of qualified employees who can develop and provide services of increased complexity, using a problem-solving mindset (Lerch & Gotsch, 2015). |
| **3** | Policies and | Curtis and Lehner (2019) identify a lack of understanding, |

| | | |
|---|---|---|
| | regulations | demonstrated in policies and regulations, of the potential to achieve sustainability-oriented advantages through PSS. Furthermore, the aforementioned lack of consensus on terminology poses a challenge to regulatory organisations. |
| **4** | Value of data | The correct visualisation and usage of data to convert it to information of value to customers may be challenging for some companies (Stark et al., 2014). There are high levels of complexity caused by data uncertainty within supply chains (Bressanelli et al., 2018). |
| **5** | Data security and privacy | Collaborative eco-systems present two significant challenges: (1) ensuring a safe data exchange (West et al., 2018) and (2) protecting intellectual property (Cimini et al., 2018; Khan & Turowski, 2016). Cybersecurity has acquired relevance as a technological issue necessary in managing a range of elements in the transformation towards digitalisation and servitisation (Cimini et al., 2018; Coreynen et al., 2017; Kuhlenkötter et al., 2017). |
| **6** | Economic feasibility | Service-based BM might transfer some financial risk from users to providers. Some documented cases have shown a mismatch between revenue and cost streams. Providers who convert their offerings into PSS provisions find themselves having to pay the solution's capital costs up-front and face high-risk contracts (Bressanelli et al., 2018b). |
| **7** | Lack of support | A lack of documented case studies makes it challenging for firms to understand how to innovate business models and identify alternatives that integrate sustainability (Barquet et al., 2016). There is also a knowledge gap in the literature when it comes to companies evaluating lifecycle thinking solutions so as to understand and capture value through service-based business models (Jiao, 2019). |
| **8** | Managerial and organisational capabilities | Lack of exploration of supply chain collaboration (Olaniyi et al., 2018; Rivas-Hermann et al., 2015), lack of supply chain visibility (Norden et al., 2013), cultural integration, lack of consultation and negotiation procedures and lack of documentation and capture of knowledge and experience (Alderton & Winchester, 2001). Some segments, such as the maritime sector, experience an overall lack of general managerial knowledge (Dourmas & Nikitakos, 2009) and prioritise technological implementations over environmental considerations. |

This thesis presents some additional findings from Study B (not found in the attached papers) exemplifying the challenges from an empirical perspective. In Study B, the authors intended to look at new alternatives, believing in the potential of service-based business models as an opportunity to deal with the increasing problem of e-waste (particularly when examining

refrigerator recycling). However, end-of-life managers have minimal visibility of the amount and state of end-of-life products they will receive at their facilities. This limits their planning capabilities and opportunity for innovative thinking.

As an enabler of new business models, there were additional challenges when exploring how to use data from end-of-life products. For instance, manufacturers might receive product information as feedback. However, refrigerators showed a high degree of variability and lack of standardisation as to the positioning of product tags showing the serial number, year of manufacture or even the name of the OEE and type of refrigerant gas. These challenges restrict the opportunity to use automated data-gathering solutions which might enable a service-based business model.

Thus, in exploring the opportunity of organising automated disassembly to fit within the framework of a service-based business model, the team proposed two alternatives: (1) using a performance or service-based, disassembly-supporting robot, or (2) by developing a new costing model whereby a disassembled compressor establishes the price. These two ideas were gathered in an early brainstorming process and require further analysis from a systematic perspective.

Technical challenges prevented further progress with the exploration mentioned above. For instance, the high variability of products makes it difficult to standardise the process of removing compressors from the back of refrigerators, as seen in Figure 3. This study tried to create an algorithm based on visual recognition. Through a workshop with the recycling plant operators, an attempt was made to identify how they currently conduct the disassembly process. Unfortunately, the amount of data required to reach a conclusion is estimated at some 100,000 images of refrigerator backs; a process which would require manual coding of each image. Developing such a database would require an extraneous use of the workforce with no guarantee of success. Although this project is on stand-by, these findings provide insights into the challenges of developing service-based business models from an end-of-life perspective.

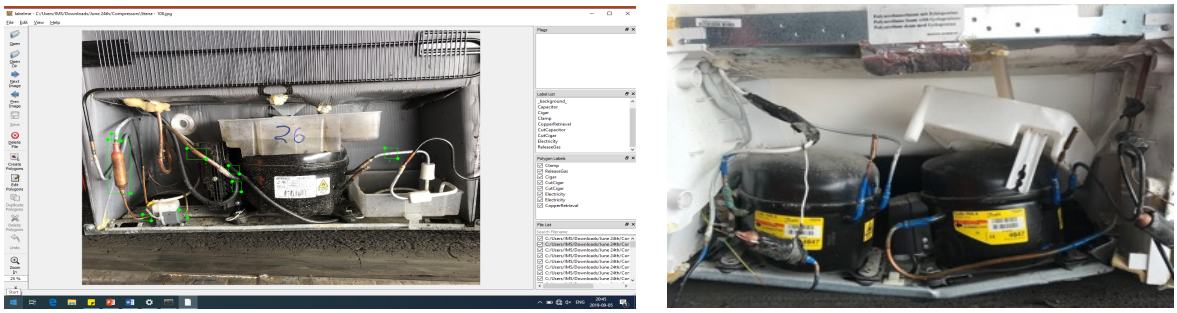

Figure 3. Refrigerator compressors

### 4.1.2. OPPORTUNITIES OF INDUSTRIAL COMPANIES TO DEVELOP SERVICE-BASED BUSINESS MODELS

The literature shows an increasing interest in exploring the potential advantages of service-based business models. There are documented success cases in which redesigning business

models, from product-centric to service-driven approaches, has incentivised companies to re-analyse their available resources. Companies are attempting to find new and more creative ways of capturing value, to enable stronger customer relationships and increase competitive advantages.

Table 4 summarises the opportunities and enablers for implementing service-based business models, based on the findings of Studies A, B and C.

Table 4. Opportunities of industrial companies to implement service-based business models

| | | |
|---|---|---|
| 1 | **Enhanced customer relationships** | Service-based business models may enable customer loyalty and business growth (Ardolino et al., 2016). Similarly, understanding how technologies can support service offerings may enable distributed knowledge, structure, ownership and customisation (Antikainen et al., 2018). |
| 2 | **New distribution channels** | Service-based business models connect to the concept of dematerialisation. PSS facilitates less tangible products because the value offering does not embed tangible assets.<br><br>Technologies such as additive manufacturing might make a positive contribution to supply chains by providing new options to develop spare parts, increase the decentralisation of production (Ardolino et al., 2013) and improve total operating downtime costs for customers. |
| 3 | **New services enabled by big data** | The development of new services may benefit from using big data (Paschou et al., 2018). Moreover, some authors (Lim et al., 2018; Marini & Bianchini, 2016; Ostrom et al., 2015) claim that big data impacts manufacturing competitiveness by promoting the capture and analysis of service-related information for effective, real-time decision making.<br><br>Potential benefits found in (Kans & Ingwald, 2016):<br>• improvement of maintenance activities;<br>• capturing data from sensors located on critical components of tangible products;<br>• transmitting captured data (e.g. temperature or pressure);<br>• keeping a record of fault codes (e.g. overheating, scheduled maintenance required);<br>• faults fed back directly to the manufacturer;<br>• storing and analysing data;<br>• manufacturers also find opportunities to develop responsive functions and actions such as repairs, clear communication, or arranging maintenance activities (Ardolino et al., 2013; |

| | | |
|---|---|---|
| | | Lightfoot, Baines, & Smart, 2013). |
| 4 | **Lifecycle visibility** | The integration of data and information undeniably helps visualise the materials cycle, as it enables sustainable value capture (Antikainen et al., 2018). Several studies (Ardolino et al., 2016; Bressanelli et al., 2018; Pagoropoulos et al., 2017) have examined how IoT, big data and analytics may facilitate a more circular economy (CE).<br><br>The use of technology can enable these seven functionalities:<br>• improving product design;<br>• attracting target customers;<br>• monitoring and tracking product;<br>• providing technical support and maintenance;<br>• optimising product usage;<br>• product upgrades;<br>• enhancing renovation and end-of-life activities.<br><br>Also, if organisations have data feeding their sustainability-oriented decision-making process, big data and analytics may positively support the advance of lifecycle management towards CE (Bressanelli et al., 2018a). |
| 5 | **Reduced need for external assistance** | "Digital competence" is the ability to take action in a digitised and knowledge-based society. This concept may define stakeholders' capability to use the advantage of symmetrical information, as it becomes digitally disseminated and collectively provided (Ardolino et al., 2016).<br><br>West et al. (2018) claim that proactive data sharing may prepare OEMs to provide support in the form of troubleshooting or providing spare parts. Data visibility might reduce the external assistance required by the customer and increase the responsibility of OEM for the performance of their PSS. Integrating augmented reality (AR) in service-based BM has been mentioned as a tool with high potential to support guidance, diagnostics and training (Roy et al., 2016). |
| 6 | **Integrated supply chains** | Understanding the value of remaining material might provide recycling companies with a better understanding of prioritising material handling. Moreover, understanding the value of material and data might help close the loop back to manufacturers in a circular supply chain (Romero & Molina, 2013).<br><br>Furthermore, Study B's conclusions predict that through strengthened supply chains with visibility along the entire lifecycle |

| | |
|---|---|
| | of a product, future scenarios might be enabled in which recycling is not the first-choice treatment. Instead, companies successfully recover the value of materials, parts, and components and thus reduce virgin material extraction and decrease the environmental impact of resource extraction. |

It is also worth mentioning that in Study C, the literature on shipping often refers to positioning digitalisation as a primary driver and initiator of new business models. Some authors located digitalisation at the centre of potential innovation, value creation and the value capture process. Data capture, processing and utilisation may increase efficiency and support decision-making on the operation and maintenance of a vessel. However, connectivity in the maritime sector has not yet reached those elements often taken for granted in manufacturing environments.

## 4.2. INCLUSION OF SUSTAINABILITY IN METHODS AND TOOLS FOR THE DEVELOPMENT OF SERVICE-BASED BUSINESS MODELS

This RQ finds answers in Studies B and D. In the extended abstract attached in Study B, this research had its first encounter with the Sustainable Value Assessment Framework, which allows the identification of uncaptured value at each stage of a lifecycle (Yang et al., 2014). This tool focuses on transforming uncaptured value into sustainable value opportunities across the whole life of a product and has helped a range of organisations discover internal and external value opportunities.

Study B also identifies the relevance of using environmental assessment methods as part of the development of service-based business models. In Paper 3, the authors repeatedly found lifecycle assessment to be an enabler of improved operations as it promoted positive sustainability perspectives.

Further, in Study D, the literature review showed many methods and frameworks focusing on the beginning-of-life or design stages. The articles analysed in this study included 28 frameworks and 19 methods. This selection showed a wide variety in the depth of their contribution to the transition from traditional manufacturing to servitisation.

Table 5. Inclusion of sustainability elements in methods and frameworks

| Type | Sustainability mentioned/included |
|---|---|
| Frameworks | (Bal & Badurdeen, 2019; Bertoni & Bertoni, 2019; Bertoni, 2019; Chen, 2018; Erkoyuncu et al., 2019; Frishammar & Parida, 2019; Guan, et al., 2019; Kristensen & Remmen, 2019; Li et al., 2021; Low et al., 2001; Mourtzis et al., 2017; Parida et al., 2019; Santamaria et al., 2016; Sousa-Zomer & Miguel, 2016; Vasantha et al., 2012; Wei et al., 2020; Wirawan et al., 2020; Xing et al., 2013) |
| Methods | (Chen et al., 2019; Chiu et al., 2015; Doualle et al., 2019; Emili, et al., 2016; Fargnoli et al., 2018; Geum & Park, 2011; Negri et al., 2016; Peruzzini & Germani, 2014; Shokohyar et al., 2012) |

However, the extent to which KPIs were included in the framework varied. Many had a more straightforward, generic approach showing further comments from the authors. Table 6 describes the elements of sustainability and KPIs included in the methods and frameworks analysed.

Table 6. Elements of sustainability addressed in methods and frameworks for service-based business models

| **Pillar of Sustainability** | KPIs or assessment points |
|---|---|
| **Environmental** | • Considers environmental sustainability qualitatively (2,4)<br>• Considers environmental impact of remanufacturing, reconditioning, product assembly, product cleaning and disposal (15,17,18,21,23,27)<br>• Design variables (6,17,18)<br>• Emissions (1, 6,18, 19)<br>• Empowers/valorises local resources (7,18)<br>• Energy consumption (1, 16-19,23)<br>• Environmental friendliness and efficiency of raw materials (1,6,17,18,23)<br>• Resource depletion (17,18)<br>• System-life optimization (7)<br>• Transportation & distribution reduction (7,17-19) |
| **Social** | • Empowers/valorises local resources (7)<br>• Fundamental issues (e.g., child labour, health and safety, corruption, freedom of religion and opinion, among others) (18,19)<br>• Improves equity and justice for stakeholders (7)<br>• Influential on economics and environment (e.g., allocation of profits, physical work conditions, psychological and organisational work conditions, job satisfaction, sustainable business partners, freedom of expression) (16-19) |
| **Economic** | • Added value for customers (7,16)<br>• Empower/valorise local resources (7)<br>• Energy consumption (17,19,23) |

| | |
|---|---|
| | • Life cost for the company (9,18,19,27)<br>• Long-term business development (7)<br>• The net present value for the company (6,18)<br>• Payback period (18)<br>• Raw material use (17,19)<br>• System life optimization (7)<br>• Total cost of ownership or use (18,23)<br>• Transportation & distribution reduction (7,17-19) |
| **Holistic sustainability perspective** | • Some tools and methods do not explicitly include KPIs, but the framework includes economic, ecologic, and social aspects as one of the upper level evaluation points (3,5,8-15,20,26,27)<br>• Map of sustainability (TBL) and efficiency (12,19)<br>• Maps of stakeholder requirements within the three sustainability dimensions (7, 10,14,15,19,22-25) |


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8. Emili, S., Ceschin, F., & Harrison, D. (2016). Product–Service System applied to Distributed Renewable Energy: A classification system, 15 archetypal models and a strategic design tool. Energy for Sustainable Development, 32, 71-98.

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## 4.3. DEVELOPING SERVICE-BASED BUSINESS MODELS IN INDUSTRIAL COMPANIES

RQ 3 finds answers in Studies A, B, C and D. In Study A, Table 7 (List of enablers for the development of sustainable service-based business models) identified those enablers whose elements may support the development of service-based business models.

Table 7. List of enablers for the development of sustainable service-based business models

| | | |
|---|---|---|
| 1 | **Strong distribution channels** | Delivery and distribution are essential to the successful delivery of services and solutions through digital challenges (Ardolino et al., 2013). Firstly, this enabler connects with Challenge 8, in which organisational capabilities pose a challenge to the implementation of service-based business models. Secondly, it connects with Opportunity 2, which states that service-based business models enable new distribution channels and are sometimes enabled by new manufacturing technologies. |
| 2 | **Big data analytics** | The development of new services might benefit from the use of big data (Paschou et al., 2018). Some authors (Lim et al., 2018; Marini and Bianchini, 2016; Ostrom et al., 2015) claim that big data impacts manufacturing by making it possible to transform data into useful information about products. This affords manufacturers an opportunity to develop responsive services such as repairs, clarifying communication or arranging maintenance activities (Ardolino et al., 2013; Lightfoot et al., 2013).<br><br>The consideration of big data analytics as an enabler connects with Challenges 4, 5 and 8. The challenges of understanding the value of data and ensuring that it is processed safely and securely requires strong organisational skills. Thus, mastery of this technology may enable the transition towards sustainable service-based business models. This relates to Opportunity 3, in which big data may enable new services. |
| 3 | **Strengthened supply chains** | In a circular supply chain, understanding the value of material and data might help close the loop back to manufacturers (Romero & Molina, 2013). Strengthened supply chains that are visible throughout the lifecycle of a product might enable future scenarios of more sustainable processes. This addresses Challenge 2, technical capabilities required to have more robust supply chains, Challenge 5 with its requirement for data security and privacy of communication across supply chains and Challenge 8, in which industry's lack of managerial and organisational capabilities may be overcome through better, more robust supply chains. It also relates to Opportunity 2, in which new distribution channels may be enabled, Opportunity 4 with its increased lifecycle visibility due to strengthened supply chains and Opportunity 6, in which integrated supply chains may be enabled by a more vital understanding of material and data. |
| 4 | **Digital capabilities** | Digital technologies might enable diversified value configuration and promote more robust partner networks (Cimini et al., 2018). IoT applications might potentially also provide visibility of maintenance |

| | | |
|---|---|---|
| | | requirements and enable life-length estimations (Fiore et al., 2019). However, using big data for service development is a complex decision requiring organisations to possess the right abilities and advanced sensing technologies (Marini & Bianchini, 2016) to use it efficiently, responsibly and sustainably (Süßeet al., 2018). It thus addresses Challenge 2 and 8 regarding technical capabilities and organisational skills. It also supports the achievement of Opportunities 1-6: enhanced customer relationships, new distribution channels, new services enabled by big data, lifecycle visibility, reduced need for external assistance and integrated supply chains. |
| 5 | **Support of methods and tools** | The use of material flow analysis and lifecycle assessment (LCA) in China to compare different end-of-life strategies for e-waste (Lu et al., 2015) suggests that lifecycle visibility enables alternatives for new business models. It addresses Challenge 7, in which lack of support is described and Challenge 8, regarding managerial and organisational capabilities. It also supports the achievement of Opportunity 5, lifecycle visibility, as it can promote the following up of designed products/services throughout their lifecycle. |
| 6 | **CSR and regulations** | Corporate social responsibility is a motivator of business shifts, through which regulatory and policy efforts have encouraged shipping to become more sustainable. This factor is also quite likely applicable to the manufacturing industry. As an enabler, it connects directly to Challenge 3 regarding policies and regulations and the need to achieve consensus. It may also enable Opportunity 2, new distribution channels enabled by stronger regulations and corporate social responsibility (in which stakeholders are assessed based on green procurement principles). And it may relate to Opportunity 4, new services enabled by big data. These are currently restricted by the lack of regulations delimiting data ownership and use. |

In Study B, through their planning of the case study, the authors suggest using the sustainable

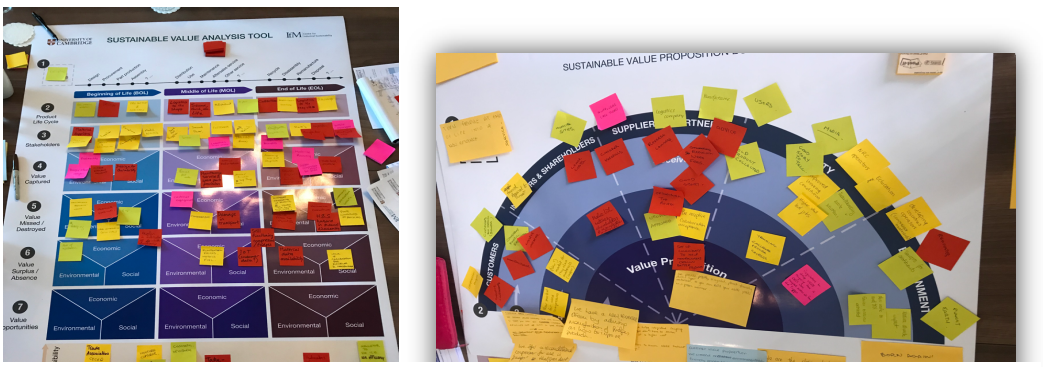


Figure 4. Use of SVAT and Sustainable Value Proposition Builder for Study B

value analysis tool (SVAT) for value creation, to tackle the industrial problem of refrigerator recycling. Researchers will provide the company with a new set of value opportunities in the BOL, MOL and EOL of refrigerators. Figure 4 evidences an initial exercise during the CISL lab organised by the University of Cambridge in 2019. Alongside SVAT, Study B also uses the Sustainable Value Proposition Builder. This approach was selected to cover the gap between research-based tools that identify value and companies that face these challenges in their operations through circular business models.

Further, Study 2 (Paper 3) includes a literature review of value elements at end-of-life for refrigerators. This search focused on finding strategies that consider looking for higher value in an end-of-life product than merely recycling its material components. For example, a higher position in the circular economy strategies pyramid, such as reuse or refurbishment, would require examination of the end-of-life product (Nguyenet et al., 2017). Circularity strategies range from high-level strategies (such as resale, reuse, repair, refurbishment and remanufacture) to low-level strategies (like repurposing, parts cannibalisation and recycling) based on their resource conservation capabilities (materials and energy) (Potting et al., 2017; Thierry et al., 1995). Therefore, templates that support strategies for a circular economy may incentivise creative thinking among decision-makers.

At any rate, it is worth noting that a rigorous and fair comparison of end-of-life handling options for domestic refrigerators is much more complicated than simply considering policy perspectives (as the waste hierarchy might suggest) (Osisanwo et al., 2015; Ranadive et al., 2018). Moreover, in practice, examining end-of-life products produces limited results, as the decision to recycle the product has already been made.

These projects propose that refrigerator manufacturers and recyclers aim to move their environmental efforts to higher levels of *circularity*. Greater efforts may be brought to bear by redesigning offerings for ease of maintenance and repair, upgradability and adaptability and by disassembly and reassembly. Thus, companies may servitise and create longer lifecycles (product lifecycle extensions) (Bakkeret al., 2014). A future research opportunity includes examining refrigerators and freezers that are included in the rent with flats and houses. (Fiore, 2018) suggests that landlords' constant contact with service and use contracts motivates the manufacturing industry to design for easier repair and refurbishment. In practice, this business model has been documented as a collection route for WEEE from private households, at a business-to-business level. The carriers contracted by a company (El-Kretsen) pick up WEEE from real estate companies, authorities and other enterprises. Then they transport it to pre-treatment facilities where recyclers handle it according to legislative requirements (Kjellsdotter Ivertet al., 2015). However, the potential to include private households and promote extended lifecycles remains to be explored.

The solutions mentioned require compromise and communication through supply chains, including suppliers, manufacturers, distributors, users and end-of-life treatment plants. A transparent communications flow may be better positioned to understand each stakeholder's prioritisation of value and find sustainable value. There is still room for exploration, even when an alternative to recycling is not viable. For instance, future research into material value requires more exploration of how to create business cases from tiny quantities of materials (using the

polymers retrieved from refrigerators). Service-based business models might pose an alternative; material-as-a-service, for example.

Additionally, exploring the two alternatives mentioned earlier in this study, (1) automation of compressor removal by image recognition and (2) servitisation of data through EOL product data collection. These two explorations showed a lack of readiness (on the part of end-of-life managers) to establish data-based services as it would be a pioneering effort. The stated lack of readiness highlights a lack of digital capability. Furthermore, the lack of standardisation of design from some products categorised as WEEE leaves recyclers with a major responsibility for innovating, as well as dealing with uncertainties more innovatively from a technological perspective.

Study C (Paper 4) then proposed a list of how literature examining the maritime sector related to the development of service-based business models:

- through the capture of experience, promoting knowledge-driven business services, with intellectual capabilities and knowledge-based professional services deemed the main source of value (Kuula et al., 2018).
- encouraging customers to contribute differently and pay for perceived value. However, achieving this transition requires leadership shifts to transform vision into strategy (Kyvik & Gjøsæter, 2017).
- Gilbert et al. (2017) suggest that positioning material at the centre of the business model, (such as reusing steel (Lorange & Fjeldstad, 2012; Wahab et al., 2018)), could reflect beneficial opportunities for profitable business models which are closer to a circular economy.
- using regulations as an incentive to integrate performance-based business models. For instance, Olaniyi et al. (2018) identify the Sulphur Emission Control Areas (SECA) as a potential enabler.
- Olaniyi et al. (2018) argued that shared ownership and distributed costs might promote the implementation of scrubber technologies as a way of reducing emissions while avoiding high implementation costs.
- some case studies found incentives in regulatory compliance. Fasoulis and Emek Kurt (2019) and Olaniyi et al. (2018) suggest selecting approaches based on the exploration of business models, ownership models and cost schemes; aiming to understand and validate the feasibility of service-based business models.
- by emphasising the fact that PSS finds great candidates in long-life products that benefit from the extended lifecycle and added services such as vessels (Pagoropoulos et al., 2017).
- Pagoropoulos et al. (2014) connect the after-sales service provision to the concept of product-service systems (PSS). They argue that new business opportunities provide benefits such as shared ownership, lower expenses and that they supporta transition to service-based business models through the guidance of senior managers.

Lastly, the recommendations for the development of tools and future frameworks resulting from Study 4 highlight the following:

- considering usability, usefulness and functionality (Farrukh and Holgado, 2020) in developing methods and frameworks for developing business models.
- using frameworks may help sell the value of sustainability to technology developers (Bertoni, 2019), especially if their concerns translate into technical attributes (Guan et al., 2019; Sousa-Zomer & Miguel, 2016).
- frameworks provide better communication of value perspective between different stakeholders (Z. Chen et al., 2019; Mont, 2002). Frameworks might also benefit from the visualisation of potential new solutions (França et al., 2017) and different scenarios (Mitake et al., 2020).
- visualisations played an important role. Clearer visuals might support the tool's usability in developing service-based business models (Frishammar & Parida, 2019).
- it might be helpful to incorporate the effects of technological advancement (Petrulaityte et al., 2020), market competition, operating conditions and logistics into the lifecycle performance fitness, costs and environmental impacts of product-service configurations (Xing et al., 2013).

# 5

# DISCUSSION

*This chapter presents a discussion of this thesis. Its results are then related to previous work and answers to the RQs are provided. Finally, the contributions of this research are highlighted and future research is indicated.*

## 5.1. THIS THESIS IN RELATION TO PREVIOUS WORK

Researchers and practitioners are increasingly looking for ways to support companies and organisations on their journey towards the most crucial goal of modern times, sustainability. The enormous relevance of initiatives that set expectations and plan for the future development of our world, such as the SDG Goals, the circular economy principles and many other field-dependent motivations, has incentivised the understanding of the status quo to create an action-oriented plan on how to develop further.

The transition towards service-based business models is a popular option. The main source of value to the customer does not relate directly to a tangible asset; rather, services are commercialised. Many authors have examined the transition known as servitisation. For instance, the pioneering contribution of Vandermerwe and Rada (1988) clarified and opened the way to exploring the value of services. Baines et al. (2007), through their extensive contributions, then identified PSS as a specific case of servitisation, defining it as the transformation of manufacturers to competing through PSS rather than products alone. In their review, Lightfoot et al. (2013) identified different fields of management research with increased interest in this field and, as they explored the topic, discussed the discrepancies between management and engineering approaches. Finally, Opresnik and Taisch (2015) identified the to alternatives that servitisation opens to new business development, drawing attention towards the efficient and effective use of data collection as a necessary leap for companies. Furthermore, Dinges et al. (2015) clearly reported that the future of servitisation requires technology and innovation to create greater value for stakeholders and achieve a competitive advantage.

The exploration of servitisation as a potential enabler of sustainability mainly takes the form of case studies published in the manufacturing industry (T. Baines et al., 2011; Cimini et al., 2018; Rymaszewska et al., 2017). However, there are fewer documented cases of companies that might benefit from service-based business models, without a clear transition from "manufacturing" to "services". Therefore, this thesis includes cases that might contribute to the existing literature from a different perspective. Also, the results contribute to the existing analysis of challenges and opportunities by exploring a selection of atypical actors, such as the specific case of refrigerator recycling and shipping service providers.

Furthermore, the study of service-based business models cannot be decoupled from digitalisation. Today's companies are inevitably undergoing a transition with the ever-increasing volume of available technologies, all with promising effects in terms of efficiency, productivity and even some sustainability benefits. However, successfully developing a company requires integration of the challenges and opportunities from a strategic perspective.

Increasingly, the literature has tried to merge the managerial knowledge required to evolve a company's business models with the necessary technical and technological support required by a highly digitalised era (Cenamor et al., 2017; Hallstedt, Isaksson, & Öhrwall Rönnbäck, 2020; Kohtamäki et al., 2020; Luz Martín-Peña et al., 2018). For example, Suppatvech et al. (2019) looked at the potential and role of IoT in enabling servitisation and Rondini et al. (2017) highlighted the relevance of simulation to PSS development. Bressanelli et al. (2018b) also identified IoT, big data and analytics as being central to usage-focused BM if a circular economy is to be realised. Although there are documented tools and methods supporting the

development of business models, there is still a lack of clarity and some mixed terminology referring to similar principles. For example, Riesener et al. (2020) referred to their work as the "development of subscription models", which are also service-based. The lack of standardised keywords and terminology may hinder the integration and progress of results and findings. Therefore, this thesis has zeroed in on methods and tools from a simplification perspective; trying to understand the extent to which they support companies in developing service-based business models that lead to sustainability.

## 5.2. ANSWERING THE RESEARCH QUESTIONS

### *RQ 1) Challenges and opportunities of industrial companies in implementing sustainable service-based business models*

Changing a company's way of operating and strategising is a highly complex process. As a result, companies face many challenges in doing so. This thesis identified a set of ten challenges to the implementation of service-based business models involving digital technologies such as big data and predictive analytics (Opresnik & Taisch, 2015), remote communications, mobile platforms (Dinges et al., 2015), IoT (Suppatvech et al., 2019).

To begin with, companies may experience difficulty in attempting to change elements of their dynamic which they have not yet fully understood. Moreover, the rapid growth of management literature which leans towards service-based business models has led to a wide range of terminologies that can create confusion and hinder communication. Similarly, the various terminologies relating to new technologies have led to uncertainty regarding definitions, requirements and potential embedded benefits.

Furthermore, making changes to managerial strategies and technological choices is neither easy nor intuitive. Therefore, both the literature and case studies report a need for companies to develop skills which incorporate an understanding of business models (Pagoropoulos et al., 2017) and digital technologies but without neglecting a deep understanding of the industrial context of the firm in which they will be applied.

Even so, for a business to be fully functioning, both sides of the coin must be included, *offer* and *demand*. Companies face many challenges, such as customers requiring time to adjust and identify new sources of value whilst visualising how their interactions have shifted. There is also the challenge of responsibilities and expectations, particularly when it involves a completely different revenue model (service-based business). These same challenges apply to the value of data (Opresnik & Taisch, 2015). Digitalisation has enabled a long list of opportunities which may be accessed, plus the capture of conclusions, ideas and intangible sources of value. However, like any change, these aspects may take time and patient communication if they are to be put across engagingly to those receiving them.

Even so, companies that investigate service-based business models and successfully tackle the challenges presented above may encounter a set of opportunities, such as establishing enhanced customer relationships (Ardolino et al., 2013). The underlying sense of collaboration inherent in this type of structure may foster exchanges that become more than one-off transactions and result in a trust-based relationship. The required structure may also create new distribution challenges involving more actors in the exchange of services based on data. Meanwhile,

companies may satisfy a customer's needs more precisely, providing visibility of the lifecycle of a tangible asset or digital offering.

Some enablers have been identified. For instance, the role of necessary regulation in smoothing this transition is still developing. The required distribution channels may be exemplified in the growing literature relating to platforms for delivering digital value (plus tools and methods suggesting how to do it). This literature may also be able to play a significant role in business development whilst instructing companies on how to manage their workforce and capacity.

***RQ 2) Inclusion of sustainability and sustainability elements in available methods and tools for service-based business models***

Companies, by nature, aim to succeed. However, the road to success can be bumpy and collaboration between practitioners and researchers may benefit from the systematisation of knowledge and documentation of lessons learned with the aim of supporting growth.

The maturity in understanding sustainability and its implications in business model development is still a work in progress. Therefore, this thesis made a careful examination of the methods and tools claiming to include sustainability as part of their definition but which then failed to include substantial elements of sustainability when operationalising the method or framework. For instance, a gap was identified in the lack of methods focusing on the middle and end-of-life of an offering, as most of them relate to designing an entirely new strategy. This may be justified by the many claims arguing that design is the lifecycle stage with the most potential influence (Calabretta et al., 2016; Sousa and da Silveira, 2017). However, existing products in the market (those in use and those approaching end-of-life) need strategies to avoid increasing environmental consequences.

This same idea may apply to service providers which follow a similar structure to those companies manufacturing one-time-purchase goods. Some industrial contexts are traditionally based on trust. These may already have engaged in values such as high perceived quality and may rely on word-of-mouth (as shown in the interviews with service-providers from the maritime sector). However, in the face of the increasing competition encountered by big actors in previously "location-based" markets, there may be a benefit in adopting a more structured approach to planning their businesses and service portfolios.

On the one hand, servitisation has been identified as a process involving distributed sources of structured and unstructured data that comes with a high level of variety and many technical requirements. There again, servitisation is a data-intensive process (Opresnik & Taisch, 2015). Indeed, data analytics is expected to be an intense driver of service development and provide a potential new source of competitive advantage (Schüritzet al., 2017).

***RQ 3) Supporting companies to develop sustainable service-based business models***

Developing sustainable service-based business models still has much potential room for growth. The design of a new support system for companies requires a deep understanding of the status quo of operations today.

The long list of available digital technologies may support and increase the reach and potential of service-based business models. However, the specific technologies that can enable a

particular type of services are yet to be explored. Still, the studies conducted in this thesis do provide some indication. For instance, the capture and use of data analytics might potentially cover previously unsatisfied needs. For example, providing visibility of a product's lifecycle and thus a better understanding of which services are required when adopting an opportunistic time approach. Similarly, the use of VR/AR has been documented to provide opportunities for external assistance during activities such as maintenance (Roy et al., 2016).

It is worth noting that this study identified a set of critical considerations in support of methods and tools yet to be developed. For instance, engaging multiple supply chain stakeholders in developing a service-based offering may enable earlier collaboration, trust and transparency. Similarly, the literature review reported that tools with good graphics might support the visualisation of opportunities and promote communication between different actors, either at an organisational level or within companies. Finally, the conceptual framework used to analyse the existing methods and tools favours prioritising concepts such as functionality, usefulness and usability.

## 5.3. METHODOLOGICAL DISCUSSION

As a PhD student, but most importantly, a researcher, this has been a journey of discovery. The initial enthusiasm and topic selection process constitute a burden and bias which cannot be overlooked. This thesis is based on a pragmatic approach, in which the development of each study involved an enthusiastic approach to finding and interweaving the necessary elements for developing a sustainable service-based business model.

When the literature has shown examples of servitisation, thinking of the big wins has been unavoidable. How did Rolls Royce achieve its successful scheme? Have we forgotten the all-time-winner case of Xerox, which became the go-to printing option for many firms? Nevertheless, there is still a lack of clarity as to which companies may benefit from service-based business models and this thesis has examined some actors which had not yet been tackled in the literature. Searching for recyclers and business models provided few hits in search engines, as was the case for service providers connected with shipping activities.

Pragmatism and social constructivism have the methodological weakness of their conclusions not being generalisable when examining a single organisation in depth. To resolve this, the author followed Dalton's approach of examining other organisations in the same field of activity. This provides confidence that elements observed in one company are most likely happening in other organisations too (Easterby-Smith et al., 2012). Thus, Dalton's idea has been replicated in this thesis. Moreover, this thesis' methodological strategy and design are fed by the solid pragmatic approach of the work performed (Creswell, 2003). There is a need to find solutions to big industrial problems which see through the lens of service-based business models. Thus, this thesis has developed a combination of literature reviews and case studies (Yin, 2018) aimed at answering the questions, what happens? Why does it happen? Has it been documented yet? Have other researchers tried to examine this organisation from the perspective of servitisation? Throughout this journey, this author has attempted to be systematic in conducting such reviews.

The strategies used to support this thesis' findings in terms of credibility are discussed in each

of the appended papers. The literature reviews have also attempted to follow methods that provided a straightforward solution to the specific task at hand.

Research Question 1

The list of challenges and opportunities presented as part of RQ1 lays no claim to generalisability or that these challenges and opportunities apply to every sector. Indeed, there may be many others in other environments. The answer to this question was produced by combining the findings from the literature on service-based business models and the exploration of two very different industrial sectors. The literature review conducted in Study A excluded articles that had the keyword "servitisation" but did not include "PSS". This decision was aimed at maintaining a manageable sample size and avoiding thematic confusion. The selection of these keywords was a consequence of the early stage of this process; the authors' preferred term now is "service-based business model". Study C then analysed eight companies (through a multiple-case study) with different organisational cultures but ultimately facing similar challenges. Therefore, it is anticipated that the list will support companies in the early stages of examining new managerial structures. There is a chance that companies with more maturity in terms of business development, sustainability and digitalisation may already have tackled these challenges. Finding and documenting their journey could prove to be a very valuable beacon for other firms.

Research Question 2

The methods and tools analysed in answering Research Question 2 are considered representative of the body of knowledge. The keyword selection and method followed are described in Paper 5. There are many methods/frameworks (some of which are well-known) which might not have appeared in the search. However, the keyword selection was sufficiently restrictive that it produced a manageable volume of documents to review. It also emphasised the relevance of using concepts systematically. Failing to do so poses a challenge and puts a burden on the growth of relevant research.

Research Question 3

The findings of Research Question 3 mainly entail providing direction whilst serving to suggest future work, based on this thesis, to researchers working to develop new support methods and tools for service-based business models and to practitioners looking for insights into how to make this transition.

## 5.4. CONTRIBUTIONS OF THIS THESIS

This thesis contributes to reducing the gap between a) the implementation of service-based business models from a managerial perspective and b) the many technical considerations in doing so. It also contributes by identifying the many challenges of implementing the service-based business models appearing in the literature and through case studies of two very different industrial sectors.

In summary, the following recommendations may be made to industrial practitioners:

- there are ten main challenges to industrial companies in adopting service-based business models: (1) customer perception, (2) data security and privacy, (3) economic

feasibility, (4) lack of organisational capability, (5) lack of support, (6) lack of systematisation of terminology referring to digital technologies, (7) lack of systematisation of terminology related to service-based business models, (8) policies and regulations, (9) technical capabilities and (10) value of data.

- there are six main opportunities for industrial companies in adopting service-based business models: 1) enhanced customer relationships, (2) new distribution channels, (3) new services enabled by big data, (4) lifecycle visibility, (5) reduced need for external assistance and (6) integrated supply chains.
- methods and tools available in the literature for developing service-based business models tend to focus on the beginning-of-lifecycle (design of an offering), leaving room for new methods and tools to support existing products.
- available methods and tools may include sustainability-related keywords but do not necessarily consider relevant elements on the triple bottom line. This restricts their potential to promote sustainable service-based business models.
- there are six main enablers which may support the transition to service-based business models: (1) big data analytics, (2) CSR and regulations, (3) digital capabilities, (4) integrated supply chains, (5) strong distribution channels and (6) support of methods and tools.

This thesis also contributes to the body of knowledge by highlighting a lack of systematisation of concepts and proposing "service-based business models" as an umbrella term to homogenise new knowledge development. The thesis also contributes to the exploration of potential new cases in industries not widely explored in previous academic work relating to servitisation. Finally, the thesis provides a set of considerations for developing new tools, methods and frameworks to support companies on their servitisation journey.

## 5.5. FUTURE RESEARCH

This thesis provides answers to the above research questions and highlights the many unexplored aspects of the topic at hand. Research and knowledge may be consolidated in a package that speaks to industry, encouraging it to change today's business-as-usual. Following research methods that support this transition offers advantages including visibility, impact and a means of lighting the way for other companies.

This thesis has consolidated a list of challenges and opportunities in implementing service-based business models. However, there is still room to explore how to tackle the identified challenges, achieve the ideal opportunities and identify new ones. Moreover, the rapid growth of technology will require a clear understanding of how to reduce the gap between the current digital capabilities of firms and the skills required in this new industrial era.

Further, this thesis has identified the strengths and weaknesses of available methods and tools from a sustainability perspective. Nevertheless, a gap has been identified and this justifies the development of a method to support organisations in the different lifecycle stages of their offering. The existing tools also tend to focus on manufacturers, leaving a gap in firms that are already providing services. New tools should showcase how to further innovate and create

services based on data and knowledge, thus feeding value chains with abundant lifecycle visibility.

Finally, this research has examined the literature and studied two very different industrial sectors; recycling and maritime shipping service providers. Future research would undoubtedly benefit from validating the results of this thesis in different industrial sectors.

# 6

# CONCLUSION

*This chapter presents the conclusions of this thesis.*

Industrial companies strive to be successful and sustainable. Service-based business models have proven an alternative by bringing benefits such as dematerialisation, competitive advantage and tighter customer relationships. This thesis provides a list of challenges, opportunities and enablers for industrial companies moving towards sustainable service-based business models. Additionally, the existing methods and tools in the literature were scrutinised, to identify how sustainability is included in the servitisation process and to what extent. Finally, this thesis provides some recommendations on how companies might develop sustainable service-based business models.

This thesis consisted of two literature reviews and two case studies, capturing both theoretical and empirical insights. Ten challenges were identified: (1) customer perception, (2) data security and privacy, (3) economic feasibility, (4) lack of organisational capabilities, (5) lack of support, (6) lack of systematisation of terminology referring to digital technologies, (7) lack of systematisation of terminology related to service-based business models, (8) policies and regulations, (9) technical capabilities and (10) value of data. These must be carefully addressed to further educate organisations, their workforce, their customers and other members in the supply chain.

Further, this thesis identifies six opportunities for implementing service-based business models: (1) enhanced customer relationships, (2) new distribution channels, (3) new services enabled by big data, (4) lifecycle visibility, (5) reduced need for external assistance and (6) integrated supply chains. Exploiting these opportunities means tackling the previously listed challenges and using these six enablers: (1) big data analytics, (2) CSR and regulations, (3) digital capabilities, (4) integrated supply chains, (5) strong distribution channels and (6) support of methods and tools.

A further conclusion is that there is room for new tools, methods and frameworks which guide companies towards the development of sustainable service-based business models. These should include a balance between quantitative and qualitative integration, digital support, specific descriptions, increased involvement of KPIs, consideration of external factors and extensive validation in different industrial sectors.

Empowering companies to capture and deliver sustainable value through effective and efficient use of sustainable service-based business models and digital technologies is (and will continue to be) an industrial priority. The many advantages visualised through digitalisation, plus an understanding of rapid world development, show companies that they must reinforce their development of organisational capability, collaborate with academia and seek an innovative environment so that the vision of this thesis may one day be realised.

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